SCIENCE FOR CERAMIC PRODUCTION

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GLAZING OF WALL CERAMICS USING AIR COOLING (A REVIEW)

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The effect of air cooling of the plasma-fused face surface of wall ceramics on the physicomechanical and decorative properties of the glaze layer are studied. A technology for glaze powder spraying on the fused surface of wall ceramics using an air jet has been developed.

Of all thermal methods for glazing construction materials, local heating is the most efficient and economically expedient [1]. For this purpose, screen furnaces are used that make it possible to heat the face surface of articles to 1073 – 1173 K in the course of glazing [2]. The most promising technologies are gas-flame and plasma fusion of the face surface of wall ceramics [3 – 5]. However, the surface layer of the ceramic brick softens and forms cracks under the action of a high-temperature energy source [6, 7]. As a result of thermal shock, the strength of adhesion of the fused layer to the base and the cold resistance are reduced.

Theoretical studies by A. I. Avgustinik, P. P. Budnikov, K. É. Goryainov, V. M. Gropyanov, G. Zal'mang, R. M. Zaiontz, W. D. Kingery, G. V. Kukolev, O. P. Mchedlov-Petrosyan, I. I. Nemets, N. N. Rykalin, L. D. Svirskii, and other domestic and foreign scientists solved the problem of obtaining heat-resistant ceramic products and coatings based on kaolins, high-melting kaolinite-hydromica clays, and other oxide materials.

The problems of the heat resistance of wall ceramics made of low-melting clays of various mineralogical compositions has not received due attention in the technical literature, except for a few studies. Thus, the authors of [8] studied the effect of thermal shock in gas-flame glazing of ceramic brick made of low-melting hydromica clays on the adhesion strength and cold resistance of the glaze layer. Heat-resistant compositions of wall-ceramic mixtures were developed and heat-removal technologies were applied in local heating [9]. The most heat-resistant mixture contains up to 40% chamotte or dehydrated clay of a specified fractional composition [10]. Preliminary moistening of the crock to 8% before fusion promotes a decrease in the thermal-shock severity and the melting point, due to conversion of ferric oxides to a highly active lower oxide [11].

In mass production of wall ceramics, it is difficult to perform preliminary moistening of the crock to a strictly determined level. The moistening operation increases the production cost, extends the production process, and requires additional production facilities and staff. When factories producing wall ceramics start using clays from new deposits, additional tests are needed, in order to develop a heat-resistant mixture capable of withstanding the thermal shock and obtain a glaze layer with good physicomechanical parameters. The introduction of chamotte or dehydrated clay into mixture compositions requires additional technological operations: preparation, weighing, and mixing with the main mixture. This calls for additional power and human resources.

The existing methods for expanding the color range of the glaze layer in local fusion of the surface of wall ceramics cannot be considered efficient. The stage of preliminary impregnation of the surface of ceramic brick with tinting metal salts is labor-consuming and technologically difficult [12]. High-temperature gas-flame spraying of colored glaze powders fosters crack formation and decreases the strength of adhesion of the glaze layer to the substrate [13].

Thus, the methodologies of technologies for producing glazed wall ceramics using thermal decoration have evolved toward increasing the heat resistance of the initial ceramic mixture and making the technological process more complicated.

Only new technological approaches intended to decrease the thermal-shock severity in fusion of the decorated surface

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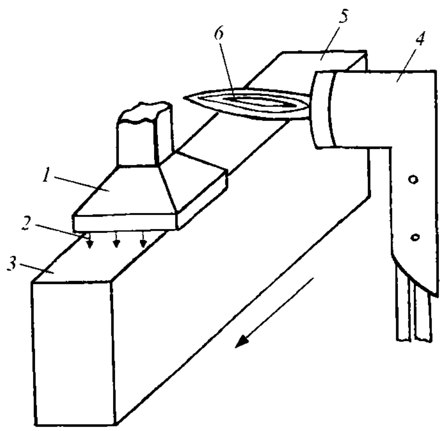

Fig. 1. Scheme of wall-ceramics glazing: *1*) air nozzle; *2*) sprayed glaze powder; *3*) glaze layer; *4*) GN-5r plasma burner; *5*) solid brick; *6*) plasma torch.

using high-energy sources allow improvement of the physicomechanical and decorative properties of the glaze layer.

The present study investigates the effect of air cooling of the surface of wall ceramics fused by a plasma torch on the physicochemical and decorative properties of the glaze layer. A technology for glaze powder spraying on the surface of wall ceramics using an air jet was developed.

Glazing was performed on solid brick M150 of size 250 × 120 × 65 mm and hollow brick M100 – 125 of the same size made of clay from the Polyana Ternovskoe deposit (Belgorod region) [14].

A study of the effect of air cooling on the physicomechanical and decorative properties of samples and the development of technological parameters for wall-ceramics decoration by the fusion method was carried out using an experimental plant. The main part of the plant was the GN-5r plasma burner of a UPU-8M plasma gun coupled with a special air jet that made it possible to cool the brick surface across the entire width of the brick face (Fig. 1). The wall-ceramic samples in the experiment were moved on an apron conveyer to the plasma burner and the air jet at a speed of 0.05 – 0.25 m/sec. The working parameters of the plasma gun were as follows: working voltage 20 – 32 V, current 350 A. Argon was the plasma-forming gas, and its consumption was 0.0014 g/sec at a pressure of 0.25 MPa. The optimum distance from the air-nozzle exit to the fused surface was determined experimentally, taking into account the air consumed in cooling. This value usually amounted to 10 – 12 mm.

In order to decrease the severity of the thermal shock and improve the glaze layer quality, plasma fusion of the face surface of ceramic brick was carried out with subsequent cooling and spraying of glaze powder (or milled tinted glass) with an air jet. The glazing process consisted in the following. Under the effect of the arc-plasma flow, a melt was formed on the ceramic surface, which on the average was heated to 2273 K. After that, the air nozzle placed at a distance of 50 mm from the plasma burner sprayed the tinted glaze powder using an air current. In the course of glaze-melt contact, the glaze became fused under the effect of the heat released by the melt. At the same time, the air kept blowing the glazed ceramic surface and intensely cooled it. The cooling stage significantly shortened the duration of the high-temperature effect, thus reducing the severity of the thermal shock and increasing the adhesive strength of the glaze layer to the substrate and its cold resistance. Substantial removal of thermal energy occurs in the course of fusion of the deposited powder.

The indicated principles of improving the physicochemical and decorative properties of the glaze layer are general and can be used in plasma treatment of wall ceramics of virtually any composition. The originality, novelty, and practical value of this technical solution were confirmed by USSR Inventor's Certif. 1116686.

To study the effect of cooling the melt by an air jet simultaneously with glaze powder spraying, the process was investigated at different rates of treatment (Table 1). Glazing was carried out using blue marblite powder with grain frac-

TABLE 1

Sample	Treatment rate, m/sec	Glaze-layer thickness,* μm	Adhesion strength, MPa		Cold resistance, number of cycles		Glaze layer porosity ("spot" method)		Glaze-surface state (visual)	
			Plasma fusion without cooling or powder spraying	Plasma fusion with cooling and powder spraying	Plasma fusion without cooling or powder spraying	Plasma fusion with cooling and powder spraying	Plasma fusion without cooling or powder spraying	Plasma fusion with cooling and powder spraying	Plasma fusion without cooling or powder spraying	Plasma fusion with cooling and powder spraying
1	0.025	(1600/2000) ± 200	0.83	1.23	5	9	Poreless	Poreless	Smooth	Smooth
2	0.050	(1200/1400) ± 100	1.12	1.68	9	18	The same	The same	The same	The same
3	0.100	(800/1000) ± 100	1.30	2.56	16	27	Porous	″	Weakly bumpy	″
4	0.150	(600/800) ± 100	1.51	2.81	21	31	The same	″	Bumpy	″
5	0.200	(400/600) ± 50	1.72	3.17	27	36	″	Porous	The same	Bumpy
6	0.250	(200/400) ± 50	2.14	3.54	32	40	″	The same	″	The same

* Above the line) without spraying glaze powder on the melt; under the line) spraying glaze powder on the melt.

TABLE 2

Sample	Air consumed on cooling, g/sec	Adhesion strength, MPa	Cold resistance, number of cycles	State of glazed surface (visual)
1	0.00093	2.15	23	With smooth spread
2	0.00116	2.35	25	The same
3	0.00140	2.56	27	"
4	0.00163	2.78	30	"
5	0.00186	2.92	32	Deformed with sags
6	0.00209	3.02	35	The same

tions of 100 – 250 μm [15]. The adhesive strength of the glaze layer to the substrate was determined using the tear-off method [16], and the cold resistance was measured by alternate frosting and defrosting until the glaze layer started to flake off the base. The porosity of the glaze coating was determined using the "spot method." The air consumption for cooling amounted to 0.0014 g/sec.

The experiments revealed the following. At high rates of fusion (0.20 – 0.25 m/sec) of the wall-ceramic surface, the duration of the high-temperature effect was reduced. Therefore, the cold resistance and the strength of adhesion of the glaze layer to the substrate show high values. However, the glazed surface is insufficiently smooth and uniform, due to the fact that the resulting melt is insufficient for uniform spread. Due to the surface-tension forces in the appearing melt drops, the glazed surface becomes nonuniform and bumpy with small hardly noticeable non-glazed spots. The "spot method" analysis indicated that in this case the glaze surface was porous (Table 1).

Under rates of treatment of 0.025 – 0.50 m/sec, the glaze layer is produced uniform, with good spread, and poreless. However, the glaze layer has low values of cold resistance and strength of adhesion to the substrate. The optimum fusion rates for the wall-ceramics surface are 0.10 – 0.15 m/sec. The decorative-coating thickness in this case is 800 – 1000 μm. The resulting glaze layer has good spread, is poreless, and has sufficiently high values of cold resistance and adhesive strength (Table 1).

Next the effect of the consumption of air arriving at the nozzle on the physicomechanical and decorative properties of the glaze layer was studied for thane optimum rate of surface fusion equal to 0.10 m/sec (Table 2). The optimum consumption of blue marblite powder was 3.25 g/sec.

It was found experimentally that at significant rates of air consumption for silicate melt cooling (0.00186 – 0.00209 g/sec), the dynamic thrust of the plasma jet deformed the silicate melt and generated sags on the brick face. This impairs substantially the decorative properties of the glaze layer. A decrease in air consumption from 0.00163 to 0.00093 g/sec reduces the heat exchange between the silicate melt and the air flow. The optimum air-consumption level appears to be 0.00163 g/sec, at which the glaze layer has uniform spread and its strength of adhesion to the substrate and cold resistance are 2.78 MPa and 30 frost-defrost cycles, respectively.

Thus, an efficient technology for glazing wall ceramics using air cooling and glaze powder spraying has been developed that makes it possible to improve the physicomechanical and decorative properties of the glaze layer.

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